Resistance is the opposition that a substance offers to the flow of electric current.

It is represented by the uppercase letter R.

The standard unit of resistance is the [ohm](https://whatis.techtarget.com/definition/ohm), sometimes written out as a word, and sometimes symbolized by the uppercase Greek letter omega Ω

When an electric current of one [ampere](https://whatis.techtarget.com/definition/ampere) passes through a component across which a potential difference ([voltage](https://whatis.techtarget.com/definition/voltage)) of one [volt](https://whatis.techtarget.com/definition/volt) exists, then the resistance of that component is one ohm

Ohm's Law is the mathematical relationship among electric [current](https://whatis.techtarget.com/definition/current), [resistance](https://whatis.techtarget.com/definition/resistance), and [voltage](https://whatis.techtarget.com/definition/voltage). The principle is named after the German scientist Georg Simon Ohm.

The ohm is the standard unit of electrical [resistance](https://whatis.techtarget.com/definition/resistance) in the International System of Units (SI ). Ohms are also used, when multiplied by imaginary numbers, to denote [reactance](https://whatis.techtarget.com/definition/reactance) in alternating-current ( [AC](https://whatis.techtarget.com/definition/alternating-current-AC) ) and radio-frequency ( [RF](https://searchnetworking.techtarget.com/definition/radio-frequency) ) applications. Reduced to base SI units, one ohm is the equivalent of one kilogram meter squared per second cubed per ampere squared (1 kg times m 2 · s -3 · A -2. The ohm is also the equivalent of a [volt](https://whatis.techtarget.com/definition/volt) per [ampere](https://whatis.techtarget.com/definition/ampere) (V/A).

# Electrical Resistance With Drinking Straws

# The CASTLE Curriculum

Let me first say that this is a genius idea. Like most of the genius ideas I’ve implemented in my classroom, they’ve come from someone else! Someones, specifically: the [Pasco Scientific CASTLE curriculum](http://www.pasco.com/file_downloads/zip_files/CASTLE_Student_Version.zip) for circuits (section 2, activities 2.7 and 2.10). I cannot rave enough at how wonderful the curriculum is, even just straight out-of-the-box.

What I love about it is the laser-like focus on conceptual underpinnings and on confronting student preconceptions head on. Discussions in my classroom focus on observations, explanations, analogies, and hypotheticals all supported with a variety of clearly observable physical evidence. I’ll be writing more about the curriculum as a whole once I complete my circuits unit. For now, I wanted to focus on this particular lesson.

# Why this idea is genius

One word: analogies.

It’s critical for students to be able to visualize what’s going on in a circuit. Otherwise their knowledge of circuits is restricted simply to how to algebraically manipulate Ohm’s Law and Kirchoff’s circuit laws. Perhaps they know how to calculate equivalent resistance in series and parallel circuits, but that doesn’t mean they have any deep understanding about electrical resistance or current. Unlike much of the mechanics content, however, we can’t literally see what’s happening in a circuit. Instead, we’ve got to use analogies.

This isn’t to say that simply being able to literally see something in physics = deep understanding. Plenty of students go through mechanics seeing all kinds of demonstrations yet still leave their class with only a “formula hunting” mindset (including myself). There’s already plenty of thorough analogies [between water flow and circuits](https://www.google.com/search?q=water+analogy+circuits&oq=water+analogy+circuits&aqs=chrome..69i57j69i61j0l4.1992j0j7&sourceid=chrome&es_sm=122&ie=UTF-8) out there. Why not just show a few slides demonstrating the water analogy and be done with it? Well…uhh… because it doesn’t work. Telling students what physics is like just. doesn’t. work.

So, what I really should have started this section out with is this.

Three words: student-constructed analogies.

This activity guides students through making directly analogous connections between air flowing through a straw (a “resistor”) and charges flowing through a circuit. It also helps them think more conceptually about resistors in series and in parallel. The best part? I don’t tell any of these connections to my students. They make all of these connections on their own. And that’s why it works!

# Setup and background

I did this after about a week of instruction with circuits. At this point, students have established the following:

1. Something is moving in the wires when the bulbs are lit or when a resistor is connected in a circuit.
2. What flows in a circuit flows in a continuous loop.
3. Resistors don’t “use up” electrical current.

Each student is given 4 coffee stirring straws and one regular drinking straw. I made sure to cut the drinking straws to be the about same length of the coffee straws to eliminate that as a variable.

Here are the questions that I have students answer, taken straight from the CASTLE curriculum packet. I skip some of them for various reasons, so here are the ones I do use along with my comments on their importance.

1. Compare the amount of time it takes you to completely exhale through a drinking straw and through a coffee straw.I let my students use their cell phones to time this. There’s quite a noticeable difference in the times, which is great. I stress to students to do a natural exhale each time and to take about the same amount of breath each time. The “same amount of breath” comes in handy for question three.
2. What other differences do you see or feel between the two straws? *I added this one myself.*I want students to use as many observations as they can to justify any explanation. The amount of time it takes to exhale is one solid piece of evidence, but I want more. It also gets students thinking about each individual piece of the experiment, which is useful for the reflection questions later on.
3. Do you exhale more air through either straw?This question is critical. A common preconception that students have about circuits is that current is “used up” (or consumed, neutralized, absorbed, etc.) to light bulbs or heat up resistors. Since students are taking the same amount of breath each time, the same amount of air is exhaled through each straw. The difference, then, is at what *rate* the air flows.  this preconception was confronted in a prior activity, and even more evidence (albeit indirect) to dash that preconception is important. Once students conclude that it’s not the amount of air that’s different, I follow up with “well, what *is* different, then?”
4. Repeat the activity with each straw, and this time direct the flow of air from the straws into the palm of your hand. What does your hand feel?Another piece of evidence that students can use later to justify their explanations and analogies.

Once students complete this observation phase, I have them answer these additional questions that I came up with.

1. Which of the straws allows for a greater flow of air? What is your evidence?
2. Which of the straws has a greater resistance to the flow of air? What is your evidence?

These questions are useful in that it establishes the crucial “facts” and sets students up to draw direct links between this activity and electrical resistance and current. My students had no issues drawing accurate conclusions, and we didn’t have to spend much time discussing these as a class.

Ok, so, that may be a tad bit exaggerated. But only by a bit! Here’s how I get the discussion started:

How is this activity analogous to electrical resistance and electrical current?

Students were puzzled at first. Some weren’t sure what “analogous” meant. Some weren’t sure how to get started. Here’s the prompt I used to help them get going: the \_\_\_ in this activity is like \_\_\_ in circuits because…

I gave students 8-10 minutes to write as much as they could drawing links between this activity and electrical resistance and current and to share their thoughts with their table mates. I asked each table to share one thing they’d come up with, and I’d write it on my whiteboard. I also encouraged students to write down ideas they saw that they didn’t come up with. The results were excellent. Here are some of the many ideas that I got:

* The air is like the charges in a circuit. It’s what’s flowing.
* Your lungs are like the batteries because they’re what’s pushing the charges. *This will be used later to tackle the preconception that batteries are the sole*source *of charges in a circuit. It also sets up an analogy they can draw later between the pressure your lungs exert and potential difference.*
* Air isn’t “used up” by pushing it through the straws, just like charges aren’t “used up” by pushing them through a resistor.
* Straws are like resistors because the air is getting crammed into the straws and is slowed down. Charges are “crammed” (or “bottlenecked”) into resistors, which slows the flow of current.
* The “effort” you exert to exhale is like the energy it takes to push charges. *This one is fantastic. Most of my classes came up with this one. I’d not even thought of it,and it helped me understand the relationship between energy and current better. Even better is that we’d not specifically tackled this difference in class, and they did it by themselves.*

The best part? **All I did here was write down student ideas.** I didn’t tell them anything. *They* came up with all the ideas all on their own! I would ask them to elaborate or clarify from time to time, but I kept my own ideas out of it. What’s also cool is that most of the ideas they came up with I hadn’t thought of, and each class contributed a new idea that a previous class hadn’t thought of. Students loved hearing from me that *they* were teaching *me* something! I was absolutely blown away by this! It’s reinforced my general belief that our society doesn’t give kids enough credit. They’re deeply creative and capable of brilliance at any age.

# Reflecting on the activity

Though I can’t quote it exactly, I’ve seen [Rick Wormeli](http://rickwormeli.net/) write that learning doesn’t happen during an activity; it happens when students reflect on the activity. This activity brought that wisdom to life for me. Without the class discussion or questions prompting students to make connections for themselves, the activity isn’t very educational. It’s like leaving kids with a cliffhanger, except they don’t know that there’s a resolution. They’re left with “well, that was easy. Wait, why did we do that again?”

Students constructing their own analogies and making their own connections is when the true learning happens. The idea behind this activity is to craft an experience such that students are armed with observations and data they collect. Then, they use these data and observations to justify their explanation on what’s happening, creating one connection point. Further than that, though, is that they draw parallel connections between two activities that seemingly have nothing to do with each other at the surface. These connections allow students to visualize a phenomena that they previously had no visualization for, or, if they had one, a sorely inadequate one. And they draw these parallels by themselves. I cannot stress the importance of that!

# Some tips on fostering quality classroom discussion

A crucial part of this activity was the classroom discussion. One could write a novel on how to do this, and I’d like to do a separate, more detailed post in the future, but here’s some bullet points for now:

* Push, push, and PUSH students to elaborate on their predictions and explanations and to justify those with evidence.  
   *That’s an interesting idea. Would you explain more about what you mean?  
  What exactly do you mean by [word/phrase]?  
  What about your observations/evidence led you to conclude that conclusion?  
  What is your evidence to support that?*
* Reinforce to students the difference between an explanation (or theory or model) and supporting evidence. Without evidence, explanations are just words, and as the denizens of Westeros like to remind us: *Words are wind!*
* Summarize explanations that students give for the rest of the class. *So, what you’re saying is [summary]. I just wanted to make sure I understood your idea. Does that sound right?* **But make sure you’re not inserting your own words or ideas!**
* Link student ideas together. If one student’s idea is related to the student that just spoke, call them out by name. *So, Billy’s idea feeds right into Cindy’s because [reasons]*. Better yet, ask the class how the two ideas are related!
* Don’t let students say “pretty much what they said”: *Ok, so you agree? Would you explain it in your own words? I want to hear what* you *think!*
* Do your best to acknowledge merit, no matter how small, in each student’s idea.
* Praise students for their ideas, and make that praise specific.